International Journal of Engineering Practical Research
IJEPR Volume 1, Issue 1, August 2012 PP. 15-20

The Derivative Orthogonal Signals Systems

Yuriy Stasev[1], Nikolay Naumenko[2], Alexandr Kuznetsov[1]
[1]Ministry of Defense of Ukraine, Kharkov Kozhedub Air Force University, Kharkov, Ukraine
[2]Ministry of Defense of Ukraine, Military Education and Science Department, Kiev, Ukraine
Email: kuznetsov_alex@rambler.ru

(Abstract) The theoretical questions of derivative orthogonal discrete signa©ls large ensemble synthesis is examined in this article. These signals possess the advanced correlation ensemble and structural properties. The practical application of the synthesized signals allows decreasing the probability of error in the communication and management network, and promoting their carrying capacity. It is shown, that the forming consequences possess the advanced ensemble and correlation properties among the well-known ones that allow increasing the quality of the data transfer in the space communication and management network.

Keywords: The Derivative Orthogonal Discrete Signals; Correlated Ensemble and Structural Properties; Characteristic Consequences; Space Communication and Management.

1. Introduction

The decision of the problem as to provide the required quality of data transfer in space communication and management networks is connected with the signals that have required correlation, ensemble and structural properties [1-10]. The practical application of the synthesized signals allows decreasing the probability of error in the communication and management network, and promoting their carrying capacity.

Among the well-known signals systems which have already found an application, the orthogonal discrete signals are of considerable interest now. The space communication and management developers' interest to the orthogonal signals systems networks is explained that their use allows decreasing the probability of error in the communication and management network, and promoting their carrying capacity.

The purpose of this article is the investigation of the theoretical questions of large ensemble of derivative orthogonal discrete signals synthesis, estimation of their correlation and ensemble properties.

The structure of the article is organized in the following way. In section 2 the methods of the derivative orthogonal signals systems synthesis are explored, the analytical estimations of correlation properties of the synthesized sequences are given. Section 3 is devoted to descriptions of experimental researches results; in particular, the results of statistical descriptions of correlation functions of the synthesized signals research and estimation of their ensemble properties are presented in the section.

Results of comparative researches of correlation and ensemble properties are brought also with the known classes of discrete signals.

2. Methods of Derivative Orthogonal Discrete Signals Synthesis

Among orthogonal signals the derivative orthogonal signals systems (DOSS) worth special attention. They possess good correlation, ensemble and structural properties. However, up to the present time the algorithms of construction are developed, and only the derivative signals systems are investigated with the number of elements $L = 2^r$, where $r = 2, 3, 4\ldots$ At the same time orthogonal signals exist practically for any values $L \equiv 0 \pmod 4$ [1].

Procedure of synthesis of the derivative orthogonal signals system consists in multiplying of elements of setting orthogonal matrix H by a signal W and is described by matrix $G = (h_{ij} \cdot w_j)$, where h_{ij} are elements of setting orthogonal signal from the ensemble H; w_j is the element of generative signal; $h_{ij}, w_j \in \{-1; 1\}$. Such algorithm of signal construction allows getting the large number of ensembles of DOSS, possessing a pseudorandom structure and good correlation properties. We will define the terms of existence and property of the derivative orthogonal signals systems.

Lemma 1. The derivative orthogonal signals systems exist for durations $L \equiv 0 \pmod 4$.

Proving. Let $g = \{g_1, g_2, ..., g_m\}$ is an ensemble of the derivative orthogonal discrete signals, received by the rule $G = (h_{ij} \cdot w_j)$, that is the value of the element j of i discrete signal is equal $g_{i_j} = h_{ij} w_j$, $j = 1, ..., L$, $i = 0, ..., m$. Let's examine two optional discrete signals $g_{i1}, g_{i2} \in g$ $(g_{i1} \neq g_{i2})$ and calculate the coefficient of their cross-correlation

$$\sum_{j=1}^{L} g_{i1_j}\, g_{i2_j}\ .$$

Using the closure property of ensemble g in relation to the operation of the elementwise addition of sequences, let's present g_{i1} and g_{i2} as sums

$$g_{i1} = g_1 + g_{i3}\,,\quad g_{i2} = g_1 + g_{i4}\,.$$

That is for any g_{i1} and g_{i2} from the ensemble $g = \{g_1, g_2, ..., g_m\}$ there will be such

$$g_{i3}, g_{i4} \in g\ \ (g_{i3} \neq g_{i4})\,,$$

that will be executed the following equalities

$$\forall j:\ g_{i1_j} = g_{1_j} + g_{i3_j}\,,\quad g_{i2_j} = g_{1_j} + g_{i4_j}\,.$$

After the substitution we have:

$$\sum_{j=1}^{L} g_{i1_j}\, g_{i2_j} = \sum_{j=1}^{L}\left(g_{1j} + g_{i3j}\right)\left(g_{1j} + g_{i4j}\right) =$$

$$= \sum_{j=1}^{L}\left(h_{1j}w_j + h_{i3j}w_j\right)\left(h_{1j}w_j + h_{i4j}w_j\right) =$$

$$= \sum_{j=1}^{L} w_j^2 h_{1j}^2 + \sum_{j=1}^{L} w_j^2 h_{1j} h_{i4j} +$$

$$= \sum_{j=1}^{L} w_j^2 h_{i3j} h_{i4j} + \sum_{j=1}^{L} w_j^2 h_{1j} h_{i3j}.$$

As $w_j^2 = 1$ and $h_{1j}^2 = 1$, the first summand is equal L. Product of the orthogonal signals is equal to zero, consequently, the second, the third and the fourth elements are equal to zero, as a result we have

$$\sum_{j=1}^{L} g_{i1_j}\, g_{i2_j} = L\ .$$

At the same time, the product

$$(g_{1j} + g_{i3j})(g_{1j} + g_{i4j})$$

is equal 4, -4 or 0, from where we have equality $L = 4t$, $t \in Z$ (Z is a great number of integers), so as a result, L is entirely divided on 4, so $L \equiv 0 (\mathrm{mod}\ 4)$.

Lemma 2. If every element of the orthogonal setting signals system to multiply by a generative signal w_j, the derived derivative system of signals is going to be orthogonal.

Proving.

$$\sum_{j=1}^{L} g_{1j}\, g_{2j} = \sum_{j=1}^{L} h_{1j}\, w_j\, h_{2j}\, w_j = \sum_{j=1}^{L} w_j^2\, h_{1j}\, h_{2j} = 0\,.$$

Lemma 3. The maximal level of side lobes of the unregulated periodic function of correlation of the derivative orthogonal signal $R_{g\,\max}$ is related to the unregulated correlation functions of setting R_h and generative R_w signals correlations:

$$R_{g\,\max}(k) \le R_w(k) - R_h(k) + L\,,\ \text{if}\ \ R_h > R_w\,;$$

$$R_{g\,\max}(k) \le R_h(k) - R_w(k) + L\,,\ \text{if}\ \ R_w > R_h\,.$$

Proving. The function of correlation of two signals is equal

$$R_g(k) = \sum_{j=1}^{L} g_j\, g_{j+k} = \sum_{j=1}^{L} h_j\, w_j\, h_{j+k}\, w_{j+k}\ .$$

Lets enter denotations $h_i\, h_{i+k} = A_i$ and $w_i\, w_{i+k} = B_i$. Then

$$R_g(k) = \sum_{j=1}^{L} A_j\, B_j\,, \tag{1}$$

where A_j and B_j are sequences, containing A_1, B_1 units and A_0, B_0 minus of units.

Thus

$$A_1 - A_0 = R_h\,,\quad B_1 - B_0 = R_w\,.$$

Let's consider that $R_h > R_w$, then in **Eq.1** the number of products $A_j\, B_j = 1$ at $A_j = B_j = 1$ is maximum equal to B_1, and at $A_j = B_j = -1$ is equal A_0. The maximal number of mismatches is equal $A_1 - B_1$. Consequently,

$$R_{g\,\max}(k) = B_1 + A_0 - \left(A_1 - B_1 \right). \tag{2}$$

Sizes A_1, B_1, A_0, and B_0 are connected with R_h, R_w, and L by correlations:

$$A_1 = 0{,}5\left(L + R_h \right);\ \ B_1 = 0{,}5\left(L + R_w \right);$$

$$A_0 = 0{,}5\left(L - R_h \right);\ \ B_0 = 0{,}5\left(L - R_w \right). \tag{3}$$

Putting **Eq.3** in **Eq.2**, we will get $R_{g\,\max}(k) \le R_w - R_h + L$. By analogy, we get $R_{g\,\max}(k)$ at $R_w > R_h$. It is necessary to remember that at

$$L \equiv 0 (\mathrm{mod}\ 4) - R_{g\,\max} = \pm m\,,$$

where $m = 0, 1, 2, ...$

It is known that R_h goes to L. Consequently, in order to get DOSS with the minimum level of side lobes of correlation function, as follows from Varakin's work [2], the generative signal must have good correlation properties.

The analysis of the well-known systems of binary discrete signals shows that most signals possess "uncomfortable" length. Multiplicity of four can be received only due to addition or truncating of signal that, naturally, will change its correlation properties and will result in the increasing of the side lobes level of periodic function of autocorrelation (PFAC) of DOSS. In this case, DOSS built with the use of descriptions of signals will possess the best correlation properties [3].

Lemma 4. If the derivative signal is formed with the use of generative characteristic signal and the setting meander-line signal, then it belongs to the system of the generative signal and has the same PFAC.

Proving. Let the productive signal be built by rule

$$H_i = \psi\left(\Theta^i + 1\right),\ \text{if}\ \ \Theta^i + 1 \equiv \left(\mathrm{mod}\ p\right),$$

where $\psi(\Theta_i)$ is the character a_i of the field element

$GF(p)$; Θ^i is the original element of the field $GF(p)$.
A setting signal is built by the rule

$$G_i^0 = (-1)^i, \quad i = 0, L-1.$$

According to the work [3] we have

$$R_d(\ell) = \sum_{i=0}^{L-1} H_i (-1)^i H_{i+1} (-1)^{i+1} =$$

$$= \sum_{i=0}^{L-1} \psi\left(\Theta^i + 1\right)(-1)^i \psi\left(\Theta^{i+1} + 1\right)(-1)^{i+1} +$$

$$+\psi\left(\Theta^\ell + 1\right)(-1)^\ell + \psi\left(-\Theta^{-\ell} + 1\right)(-1)^{-\ell} =$$

$$Z + \psi\left(-\Theta^\ell + 1\right)(-1)^\ell + \psi\left(\Theta^\ell + 1\right)(-1)^{-\ell}. \quad (4)$$

Taking into account the properties of function of the field element character, we present a component Z **Eq.4** like

$$Z = \psi\left(\Theta^\ell\right) \sum_{i=0}^{p^n-1} \psi\left(\Theta^i + 1\right) \psi\left(\Theta^{i+1} + \Theta^{-\ell}\right) (-1)^i (-1)^{i+1}. \quad (5)$$

Passing into **Eq.5** from a sum on the index i to the sum on all of nonzero elements of the field $GF(p)$, we get

$$E = \sum_{i=0}^{p^n-1} \psi\left(\Theta^i + 1\right) \psi\left(\Theta^i + \Theta^{-\ell}\right)(-1)^i (-1)^{i+\ell} =$$

$$= (-1)^\ell \sum_{\substack{a_i \in GF(p) \\ a_i \neq 0 (\mathrm{mod}\ p)}} \psi\left(a_i + 1\right) \psi\left(a_i + \Theta^{-\ell}\right)(-1)^{2\ell}. \quad (6)$$

We indicate $C_i = a_i + 1$. Taking into account that $(-1)^2 = 1$, and also that C_i runs about all the elements of the field, except 1, if a_i runs about all the nonzero elements of the field $GF(p^n)$, **Eq.6** is like

$$E = (-1)^\ell \sum_{\substack{C_i \in GF(p) \\ C_i \neq 0 (\mathrm{mod}\ p)}} \psi\left(C_i\right) \psi\left(C_i + \Theta^{-\ell} - 1\right). \quad (7)$$

Adding and subtracting $\psi(\Theta^{-\ell})$, taking into account that $\psi(0) = 0$, **Eq.7** can be presented like

$$E = (-1)^\ell \sum_{C_i \in GF(p)} \psi\left(C_i\right) \psi\left(C_i + \Theta^{-\ell} - 1\right) - \psi\left(\Theta^{-\ell}\right) =$$

$$= (-1)^\ell \sum_{\substack{C_{\omega} \in GF(p) \\ C_i \neq \ell (\mathrm{mod}\ p)}} \psi\left(C_i\right) \psi\left(C_i + \Theta^{-\ell} - 1\right) - \psi\left(\Theta^{-\ell}\right) =$$

$$= (-1)^\ell \sum_{\substack{C_i \in GF(p) \\ C_i \neq \ell (\mathrm{mod}\ p)}} \psi\left(C_i^2\right)\left[1 + \left(\Theta^{-\ell} + 1\right) C_i^{\mu-1}\right] - \psi\left(\Theta^{-\ell}\right) =$$

$$= (-1)^\ell \sum_{\substack{C_i \in GF(p) \\ C_i \neq 0 (\mathrm{mod}\ p)}} \left[1 + \left(\Theta^{-\ell} - 1\right) C_i^{\mu-1}\right] - \psi\left(\Theta^{-\ell}\right).$$

If

$$C_i \in GF(p^n), \quad C_i \equiv 0 (\mathrm{mod}\ p),$$

than $C_i^{\mu-1}$ runs about all the elements of the field, except 1.
If $b_i = C_i^{\mu-1}$, $d = \Theta^{-\ell} - 1 \in 0 (\mathrm{mod}\ p)$, than

$$E = (-1)^\ell \sum_{\substack{b_i \in GF(p) \\ b_i \neq 0 (\mathrm{mod}\ p)}} \psi\left[1 + d\, b_i\right] - \psi\left(\Theta^{-\ell}\right). \quad (8)$$

Taking into account that

$$\sum_{\substack{x \in GF(p) \\ x \neq 0 (\mathrm{mod}\ p)}} (\nu x + k) = -\psi(k),$$

we write down **Eq.8** like

$$E = (-1)^\ell \left[-1 - \psi\left(\Theta^\ell - \ell\right)\right]. \quad (9)$$

Putting **Eq.9** in **Eq.4**, **Eq.5**, and **Eq.6**, we get

$$R_d(\ell) = \psi\left(\Theta^\ell\right)(-1)^\ell \left[-1 - \psi\left(\Theta^{-\ell}\right)\right] +$$

$$+\psi\left(-\Theta^{-\ell} + 1\right)(-1)^\ell + \psi\left(-\Theta^{-\ell} + 1\right)(-1)^\ell. \quad (10)$$

Supposing that $L = 0 (\mathrm{mod}\ 4)$, and also taking into account, that $\psi(-1) = 1$ [4] and $(-1)^\ell = (-1)^{-\ell}$, we rewrite **Eq.10** like

$$R_d(\ell) = (-1)^\ell \left\{\left[-1 - \psi\left(\Theta^\ell\right)\right] +\right.$$

$$\left. +\psi\left(\Theta^\ell - 1\right)\left[1 + \psi\left(\Theta^\ell\right)\right]\right\}. \quad (11)$$

It follows from **Eq.11**:

$$\text{at } \psi\left(\Theta^\ell\right) = 1, \; \psi\left(\Theta^\ell\right) - 1 = 1, \; R_d(\ell) = 0; \quad (12)$$

$$\text{at } \psi\left(\Theta^\ell\right) = 1, \; \psi\left(\Theta^\ell\right) - 1 = -1, \; R_d(\ell) = 1; \quad (13)$$

$$\text{at } \psi\left(\Theta^\ell\right) = -1, \; \psi\left(\Theta^\ell\right) - 1 = 1, \; R_d(\ell) = 0; \quad (14)$$

$$\text{at } \psi\left(\Theta^\ell\right) = -1, \; \psi\left(\Theta^\ell\right) - 3 = -1, \; R_d(\ell) = 0, \quad (15)$$

for $L \equiv \mathrm{mod}\left(\mathrm{mod}\ 2\right)$.

The analysis of **Eq.11** shows that events **Eq.12** and **Eq.15** are impossible, because Θ^ℓ and $\Theta^\ell - 1$ can not be even and odd simultaneously.

Thus, the derivative signal, that built with the use of meander-line signal, as a setting one, has the same PFAC, like the generative signal.

PFAC and the periodic function of cross-correlation (PFCC) of the derivative orthogonal signal systems is determined from expression

$$R_{jk}(n)=\sum_{m=1}^{L} a_j(m)\,a_k(m+n)\,. \qquad (16)$$

For $j=k$ as to **Eq.16** it is possible to define the side lobes of PFAC, and for $j \neq k$ it is possible to define the side lobes of PFCC.

For the estimation of values of side lobes level of correlation functions in **Eq.16** we make a replacement like

$$f_m = a_j(m)\,a_k(m+n)\,.$$

Then the side lobes level of correlation function will be determined by the difference between the number of positive and negative members of sequence f_m. Difference between the number of positive and negative members of sequence is accepted to nominate as its weigh W [2].

It follows from that fact, that distribution of probability of side lobes of two signals correlation function provided that they have M blocks $p_R(W/\mu)$, can be determined by the probability of receipt of weight W in a sequence f_m at presence of μ blocks in signals a_j and a_k.
It is shown by Varakin [2] that $p_R(r/\mu)$ is determined from the expression

$$p_R(W/\mu)=\sum_{\mu=1}^{M} p_w(r/\mu)\,p(\mu/M)\,,$$

where $p_w(r/\mu)$ is probability of receipt of weight $W=r$; $p(\mu/M)$ is probability of transition of sign in a sequence f_m, having M blocks.
Probability of receipt of weight is determined by the expression

$$p_w(r/\mu)=\frac{L(W/\mu)}{L(M)}\,,$$

where

$$L(W/\mu)=C^{\mu+1}_{(L+W)/2-1}\,C^{\mu-1}_{(L-W)/2-1}+C^{\mu-1}_{(L-W)/2-1}\,C^{\mu+1}_{(L-W)/2-1}$$

is number of signals in the whole code, which has the weigh W and the number of blocks μ;

$L(\mu)=2C^{\mu-1}_{L-1}$ is the general number of signals with μ blocks;

C^x_y – the number of combinations from y on x;

μ^+ – the number of single blocks;

μ^- – the number of zero blocks;

$\mu^+=\mu^-=\mu/2$ – at even μ;

$\mu^+=(\mu+1)/2$, $\mu^-=(\mu-1)/2$ – at odd μ.

$$p(\mu/M)=\frac{(L-M_1)(M_2-1)+(L-M_2)(M_1-1)}{(L-1)^2}\,, \qquad (17)$$

where M_1 is a number of blocks in a signal a_j, M_2 is a number of blocks in a signal a_k.
At the subtraction of PFAC $M_1=M_2$, and **Eq.17** turns into like

$$p(\mu/M)=\frac{2(L-M)(M-1)}{(L-1)^2}\,.$$

However, the number of blocks M in a derivative sequence can be changed within the scope of

$$|M_1-M_2|+1\le\mu\le\begin{cases} M_1+M_2-1, \text{ at } M_1+M_2\ge L+1;\\ 2L-M_1-M_2+1, \text{ at } M_1+M_2\le L+1,\end{cases}$$

and probability of receipt of derivative signal with μ blocks is described by the binomial law of distribution:

$$p(\mu/M)=C^{\mu-1}_{L-1}\,p_1^{\mu-1}(1-p_1)^{L-\mu}\,.$$

Thus, at the known number of blocks in the setting and the generative signal it is possible to calculate the probability of appearance of value of side lobe level of correlation function.

3. Correlated and Ensemble Properties of Derivative Orthogonal Discrete Signals

The researches results of dependence $|R_{g\max}|$ of PFAC and PFCC from L if $p_R(r_{\max}/M)<<1/L$, have shown that the value $|R_{g\max}|$ for PFAC can not exceed $3{,}25/\sqrt{L}$, and for PFCC – $3{,}96/\sqrt{L}$.

It is known [2] that the average probability of error, probability of false alarm and signal missing in communication network depend not only on the maximal values of PFAC and PFCC but also on statistical descriptions of correlation functions of signals. Statistical descriptions of PFAC and PFCC: expectation value m; mean value of the expectation value m_{mean}; dispersion of side lobes level of correlation functions $D_{D_{mean}}$; the mean value of maximal level $U_{\max}$ and mean value of dispersion of side lobes level of correlation functions $D_{U_{\max}}$ was calculated with the use of method, shown in the work of Bel'tyukov and Sivov [4]. The results of researches and averaged values of descriptions of PFAC and PFCC are presented in **Table 1**.

In **Table 2** the mean values of estimations of statistical descriptions of PFAC and PFCC of the derivative orthogonal signal systems, complete code rings, nonlinear derivates of code sequences (NDCS), and also Gold's sequences are resulted [3].

Analysis of **Table 1** and **Table 2** shows that the rationed values of PFAC and PFCC of derivative orthogonal signal systems with the number of elements $L\equiv 0\,(\mathrm{mod}\ 4)$ less than, for Gold's sequences and orthogonal signal systems, that built on the basis of complete code rings and NDCS. Consequently, the use of DOSS with the number of elements $L\equiv 0\,(\mathrm{mod}\ 4)$ will allow as follows from Varakin's work [2],

to decrease probability of error or to increase the carrying capacity of communication network.

At the construction of space communication and management networks along with the correlation descriptions ensemble descriptions of in-use signals have an important value. Ensemble properties of DOSS depend on the number of methods of construction of Hadamard matrices S_h, ensemble descriptions of generative signals and determined by the expression

Table 1 CORRELATION FUNCTIONS PARAMETERS

Number of elements in the signal	CF	m	m_{mean}	D_{mean}	$D_{D_{mean}}$	$U_{\max}$	$D_{U_{\max}}$
12	PFAC	$0.6\cdot10^{-1}$	$2.6\cdot10^{-4}$	$3.7\cdot10^{-2}$	$4.4\cdot10^{-2}$	0.235	$3.8\cdot10^{-2}$
	PFCC	$3.8\cdot10^{-2}$	$7.5\cdot10^{-1}$	$5.6\cdot10^{-2}$	$0.4\cdot10^{-1}$	0.380	$2.1\cdot10^{-3}$
16	PFAC	$7.2\cdot10^{-2}$	$3.6\cdot10^{-5}$	$1.2\cdot10^{-2}$	$2.9\cdot10^{-4}$	0.171	$2.4\cdot10^{-2}$
	PFCC	$1.1\cdot10^{-2}$	$7.3\cdot10^{-1}$	$3.1\cdot10^{-2}$	$5.4\cdot10^{-5}$	0.500	$2.4\cdot10^{-2}$
60	PFAC	$0.4\cdot10^{-1}$	$1.1\cdot10^{-5}$	$0.9\cdot10^{-2}$	$0.9\cdot10^{-5}$	0.090	$0.1\cdot10^{-2}$
	PFCC	$3.3\cdot10^{-2}$	$0.5\cdot10^{-1}$	$1.5\cdot10^{-2}$	$6.4\cdot10^{-7}$	0.330	$1.8\cdot10^{-3}$
108	PFAC	$4.3\cdot10^{-2}$	$1.5\cdot10^{-5}$	$4.3\cdot10^{-3}$	$4.6\cdot10^{-5}$	0.055	$1.7\cdot10^{-3}$
	PFCC	$4.5\cdot10^{-2}$	$0.9\cdot10^{-1}$	$0.8\cdot10^{-2}$	$8.4\cdot10^{-7}$	0.250	$2.1\cdot10^{-3}$
256	PFAC	$1.9\cdot10^{-2}$	$4.4\cdot10^{-6}$	$3.4\cdot10^{-3}$	$3.6\cdot10^{-7}$	0.047	$1.8\cdot10^{-4}$
	PFCC	$2.9\cdot10^{-2}$	$8.7\cdot10^{-1}$	$4.4\cdot10^{-3}$	$1.2\cdot10^{-6}$	0.190	$1.5\cdot10^{-3}$
Averaged values	PFAC	$0.312/\sqrt{L}$	$0.9\cdot10^{-4}$	$0.05/\sqrt{L}$	$1.8\cdot10^{-5}$	$0.684/\sqrt{L}$	$1.5\cdot10^{-3}$
	PFCC	$0.367/\sqrt{L}$	$4.5\cdot10^{-1}$	$0.12/\sqrt{L}$	$3.3\cdot10^{-6}$	$(1\div3)/\sqrt{L}$	$1.5\cdot10^{-1}$

Table 2 THE COMPARATIVE ANALYSIS OF THE CORRELATION FUNCTIONS PARAMETERS DOSS AND OTHER SEQUENCES

Type of consequence	CF	$M/\sqrt{L}$	D_{Mmean}	$D_{mean}L$	$D_{D_{men}}$	$U_{\max}\sqrt{L}$	$D_{U_{\max}}$
DOSS	PFAC	0.312	$0.90\cdot10^{-4}$	0.050	$0.180\cdot10^{-4}$	0.684	$0.150\cdot10^{-2}$
	PFCC	0.367	$0.45\cdot10^{-4}$	0.120	$0.330\cdot10^{-5}$	$1\div3$	$0.150\cdot10^{-2}$
Complete code rings	PFAC	0.433	$0.78\cdot10^{-6}$	0.146	$0.113\cdot10^{-6}$	1.5	$0.145\cdot10^{-3}$
	PFCC	0.480	$0.79\cdot10^{-6}$	0.082	$0.211\cdot10^{-6}$	$0.5\div0.75$	$0.160\cdot10^{-2}$
NDCS	PFAC	0.750	$0.35\cdot10^{-3}$	0.321	$0.372\cdot10^{-3}$	2.16	$0.300\cdot10^{-2}$
	PFCC	0.730	$0.19\cdot10^{-3}$	0.358	$0.117\cdot10^{-4}$	2.22	$0.117\cdot10^{-1}$
Gold's sequences	PFAC	0.750	$0.39\cdot10^{-4}$	0.310	$0.460\cdot10^{-4}$	1.52	$0.207\cdot10^{-2}$
	PFCC	0.740	$0.25\cdot10^{-4}$	0.440	$0.360\cdot10^{-4}$	1.52	$0.540\cdot10^{-5}$

$$S = S_h\, S_w\, L\,.$$

In **Table 3** is given the comparative analysis of ensemble descriptions of DOSS and characteristic sequences, that have the best ensemble, correlation and structural properties among the known binary signals that exist for a wide spectrum durations

$$L = 4x \quad \text{and} \quad L = 4x + 2\,, \quad x = 2, 3, 4, \ldots$$

Data from the **Table 3** testify that the number of DOSS exceeds the number of characteristic sequences considerably.

4.Conclusion

Thus, the derivative orthogonal signals systems with the number of elements $L \equiv 0 \pmod 4$ have the improved ensemble and correlation properties among the known

signals systems that allow improving data transfer in space communication and management networks.

Table 3 THE COMPARATIVE ANALYSIS OF THE ENSEMBLE CHARACTERISTICS DOSS AND CHARACTERISTIC SEQUENCES

L	DOSS	Characteristic sequences
40	$3.8{\cdot}10^3$	14
100	$8.0{\cdot}10^3$	38
256	$1.5{\cdot}10^7$	128
1032	$1.3{\cdot}10^8$	336
2088	$5.4{\cdot}10^8$	672
9000	$8.0{\cdot}10^9$	2400

References

[1] Gorbenko I. D., Stasev Yu. V. The derivative orthogonal signals systems analysis // Radiotehnica. – 1989. – № 9. – pp. 16-18. (in Russian).

[2] Varakin L. E. Signals systems theory. – M.: Sov. radio, 1978. – 304 p. (in Russian).

[3] Sverdlik M. B. Optimal discrete signals. – M.: Sov. radio, 1975. – 200 p. (in Russian).

[4] Bel'tyukov V. V., Sivov V. A. Construction of the periodic function of the derivative orthogonal signals systems cross-correlation // Radiotehnica i Elektronika – 1982. – № 9. – pp. 1773-1778. (in Russian).

[5] N. I. Naumenko, Yu. V. Stasev, A. A. Kuznetsov. Methods of synthesis of signals with prescribed properties // Cybernetics and Systems Analysis, Vol. 43, N3. – 2007, pp.321-326, DOI 10.1007/s10559-007-0052-8, URL http://dx.doi.org/10.1007/s10559-007-0052-8.

[6] Yu. V. Stasev, A. A. Kuznetsov, A. M. Nosik. Formation of pseudorandom sequences with improved autocorrelation properties // Cybernetics and Systems Analysis, Vol. 43, N1. – 2007, pp. 1-11, DOI 10.1007/s10559-007-0021-2, URL http://dx.doi.org/10.1007/s10559-007-0021-2.

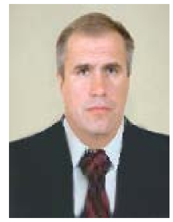
[7] N. I. Naumenko, Yu. V. Stasev, A. A. Kuznetsov, S. P. Evseev. Theory of signal-code constructions. Kharkov.: Kharkov Kozhedub Air Force University, 2008. – 489 p. (in Russian).

[8] Digital methods in space communication. /Edited by S. Golomba. – M.: Sviaz, 1969. – 272 p.

[9] Skliar B. Digital communacations. Fundamentals and applications. – New Yersey: Prentice Hall PTR, 2001. – 1104 p.

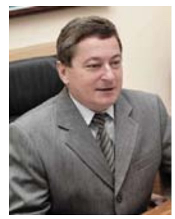
[10] Stasev Y., Kuznetsov A., Sai V., Karpenko O. Discrete Signals with Multi-Level Correlation Function // Statistical Methods of Signal and Data Processing (SMSDP-2010): Proceedings. – Kiev: National Aviation University "NAU-Druk" Publishung House – 2010. – pp. 176-179.

Author Introduction



Yuriy Stasev, Kharkov Kozhedub Air Force University, Kharkov, Ukraine.

The field of scientific interests: signal-code sequence theory, methods of complex signals great ensemble synthesis with improved correlation and ensemble features.



Nikolay Naumenko, Military Education and Science Department of the Ministry of Defence of Ukraine, Kiev.

The field of scientific interests: statistic communication theory, the coding interference immunity theory, methods of complex signals forming.

Alexandr Kuznetsov, Kharkov Kozhedub Air Force University, Kharkov, Ukraine.

The field of scientific interests: the coding interference immunity theory, methods of complex signals forming, cryptography and authentication.